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PUBLICATIONS SECTION

Gross Job Time Studies--

An Efficient Method for Analyzing Forestry Costs

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Cost data from past forest operations are necessary for estimating the costs of future forestry jobs. If the job estimates appear excessive, cost data may indicate which operations could be modified to bring total costs down to an acceptable level. If costs are so high that an important forestry job cannot be done, cost data are needed to determine which operations need to be done in an entirely new way. When cost levels are not considered a problem, cost data are still needed to control total production for a given investment, and where investment outcome is considered in detail, for optimizing total returns.

Ordinarily three sources of cost data are exploited for these purposes:

1. Accounting data are often interpreted to determine the cost of doing forestry jobs. Such information is gathered for financial statements, however, and needs considerable adjustment to be used for costing a particular forestry job or operation. Often financial statements lack flexibility for estimating future jobs; frequently, necessary adjustments cannot be made at all.

2. Time-and-motion study results are available for many forestry jobs, but are not usually as useful in forestry as they are for industrial plant cost estimates because the variability in woods conditions is far greater than in industrial plants.

3. Special cost studies, if carefully conducted, can supply good data for local situations and a variety of uses.

A special cost study method is described here[3] in which cost data are collected for satisfying most cost objectives. It is a flexible, field-efficient, formal system of data collection to answer a number of pertinent cost questions. Described are the necessary

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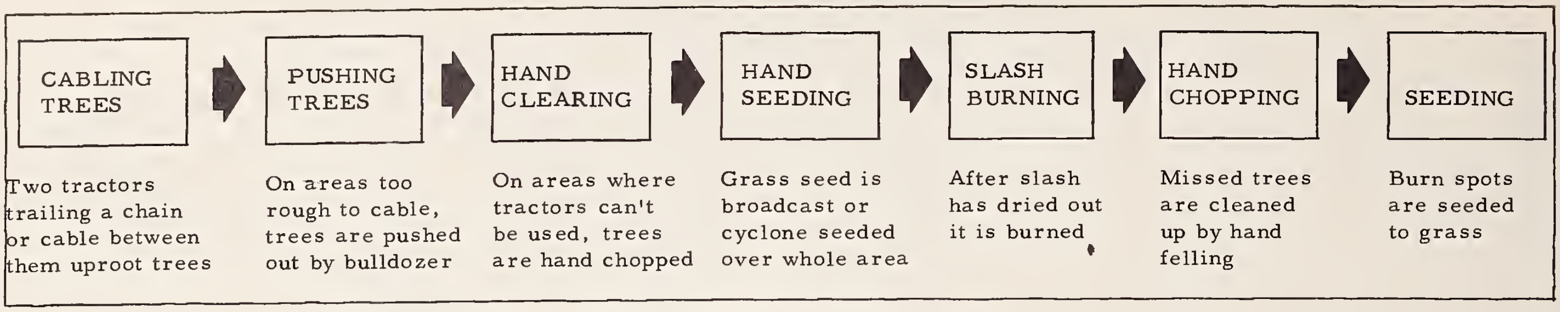


Figure 1.--This sample flow chart shows seven steps set up for the project of converting pinyon-juniper-covered areas to grass- and herb-covered areas on the Beaver Creek Pilot Watersheds in Arizona. The first three jobs could have been combined into a "juniper clearing" job. The two "hand-seeding" jobs could have been combined. Slash burning and hand chopping could have been lumped together as a "cleanup" job.

planning, data collection, and analysis methods to present a practical cost-determination system for field use.

General Method

Physical input-output data are collected rather than dollar costs and returns because it is easier to generalize from the former. Inputs collected include labor time, equipment time, direct supervision time, and materials. Other elements--travel time and machine inputs, for example--can be collected where these are to be analyzed. Outputs specify total production as acres treated, trees thinned, etc. Dollar costs of production are determined by multiplying inputs by appropriate wage rates, machine rates, and material costs. The sum of costs divided by the number of production units accomplished gives average unit costs.

Planning the Cost Study

Planning the cost study begins by breaking a treatment operation down into its component jobs. In this respect, it is similar to operational planning.

A flow chart (fig. 1) is a good means of breaking down a treatment operation, and sets the stage for the jobs to be costed. It is in this phase of planning that the cost analyst sets limits on what costs should be collected. The flow chart tells us the general job objectives, but does not describe it.

The second planning step is to describe each job by listing the inputs to be recorded, the output unit to be recorded, and the job conduct as far as crew organization is concerned. The job descriptions need to set forth a clear understanding of how the jobs will be done, and to describe each job in detail. For example, to perform the cabling operation, we need to know: what size are the tractors? how are they equipped? is there a swamper for each or both? how long and what size is the cable or chain? need we collect machine inputs to determine a machine rate? what field servicing is done? what output units shall we use? Also, if we plan to tie to a time-and-motion study, its requirements need to be met. Since all these questions need to be resolved anyway for conducting the operation, the formal job description is not a big task, but it is important.

Collecting the Field Data

Data are collected on a specially imprinted 3- by 5-inch card (fig. 2), which provides for collecting basic input-output data. The back of the card is left blank, but additional supporting data could be incorporated there. For special situations the basic data format could be changed, but all elements shown in figure 2 need to be included. The job foreman records the data; the forester or

JOB Slash burning DATE 12/20/63

LOCATION Watershed 1 (see map)

EQUIPMENT 5 real tite drip torches

MATERIALS 17 gals. fuel mixture 1/10 gasoline to fuel oil.

MEN	HRS.	MEN	HRS.	
C.G.	7			TOTAL PRODUCTION (see map) 72 acres (D.W.)
S.V.	7			TOTAL MAN HOURS 35
R.C.	7			SUPERVISOR C.L. Working Foreman
W.D.	7			HOURS 7

JOB: Name of the job from the flow chart.

LOCATION: Designation of the treatment area.

EQUIPMENT: Kinds and numbers of equipment, and the hours or miles of use of each.

MATERIALS: Kinds and quantities of expended items. If machine rates are desired, items such as fuel, grease, oil filters, etc. can be included.

MEN AND HOURS: Initials of the men on the job and number of hours and fractions thereof that each was on this job. If, for example, two jobs are being conducted concurrently, a man might shift from one to the other. He would be dropped from one job card and would be picked up on the other job card. A case in point might be a thinning operation where one crew is felling and another is piling slash. If the felling crew got too far ahead of the piling crew, the foreman might drop some fallers off to pile for awhile. He would carry them on the slash-piling card while they were with that job.

TOTAL PRODUCTION: Number of production units. Some types of production units are difficult for a foreman to measure--acreage, for example. He can indicate the ground covered on a map or with a trace in the field, and the supervisor can planimeter the map or check the field. In this case the foreman would merely indicate "see map" to show where production units are to come from. The cards can be held for extended periods without posting daily production so as to get periodic production, or held until an area is completed.

SUPERVISOR AND HOURS: Initials and hours on the job. A foreman may divide his time between more than one job, as in the thinning case above. In this event, he would use his judgment to prorate his time.

APPROPRIATE REMARKS may be entered on the back of the card to help interpret the data: equipment breakdown, work slowdown due to weather, or unusual ground conditions.

Figure 2.--Job card for collecting field data, with detailed instructions on its use. Handwritten entries apply to the "slash burning" operation in the flow chart shown in figure 1.

supervisor in charge of the operation collects the cards daily and checks for accuracy or omissions.

The handwritten entries in figure 2 apply to the slash burning in the conversion operation shown in the flow chart (fig. 1). All entries except production are easily made by the foreman. In this case the day's production was shown on a map, which was later planimetered for acreage. Since the foreman both directed and worked on the slash-burning operation, his time was included in total man-hours. Additional input data can be obtained from this card. For example, the crew is paid for an 8-hour day. One hour then must have been used in some other way. Custom dictates that one-way travel be done on the worker's own time. The hour not recorded was probably travel on working time. Reference to a map

shows the job location as 35 miles from the headquarters station; part of the travel is over rough, work trails. If the full 8 hours is to be accounted for, this rationalization could be documented on the back of the job card, or travel could be considered a special job subject for another card.

Summarizing the Data

To put the data into a form for analysis, a physical summary is made directly from the job cards. This chronological summary of the production can be converted easily to a cost summary. Job 2 from the flow chart (pushing trees) was used as an example (fig. 3). Given a machine rate of $12 per hour and a labor rate of $3 per hour, the physical summary was converted to a cost summary.

To compare results with those from an earlier study, data characterizing the independent variable of the earlier study are needed. For example, Cotner and Jameson[4] conducted an earlier time-and-motion study of pushing junipers, in which the independent variable was the number of trees per acre by height classes. To adapt data collected for the pushing job on Beaver Creek (fig. 3), we determined the number of trees per acre by height classes, entered that number in their time-and-motion study equation, and calculated the expected production to be 0.9 machine hour per acre. Cotner and Jameson suggest that the calculated rate should be within 10 percent of the actual rate. This requirement is met by the data for Beaver Creek, since the actual rate of 0.822 hour per acre is within 10 percent of the calculated rate.

As shown in the above juniper-pushing example, a time-and-motion study yields an equation that enables one to predict the cost of pushing stands of different density.

From the gross time study method, similar types of information can be developed by gathering data covering a number of conditions. A production-rate equation was thus developed for thinning precommercial ponderosa pine on Beaver Creek (fig. 4), in which 148 daily crew observations were included. Data were analyzed to show number of trees thinned per chainsaw hour for areas with thinning densities that varied from 100 to 1,500 trees per acre. Dollar costs then were computed, based on actual labor rates and published saw rates, to obtain the direct cost of $2.75 per chainsaw hour. From the additional

[4]*Cotner, M. L. and Jameson, D. A. Costs of juniper control: Bulldozing vs. burning individual trees. Rocky Mountain Forest and Range Expt. Sta., Sta. Paper 43. 14 pp., illus. 1959.*

JUNIPER PUSHING

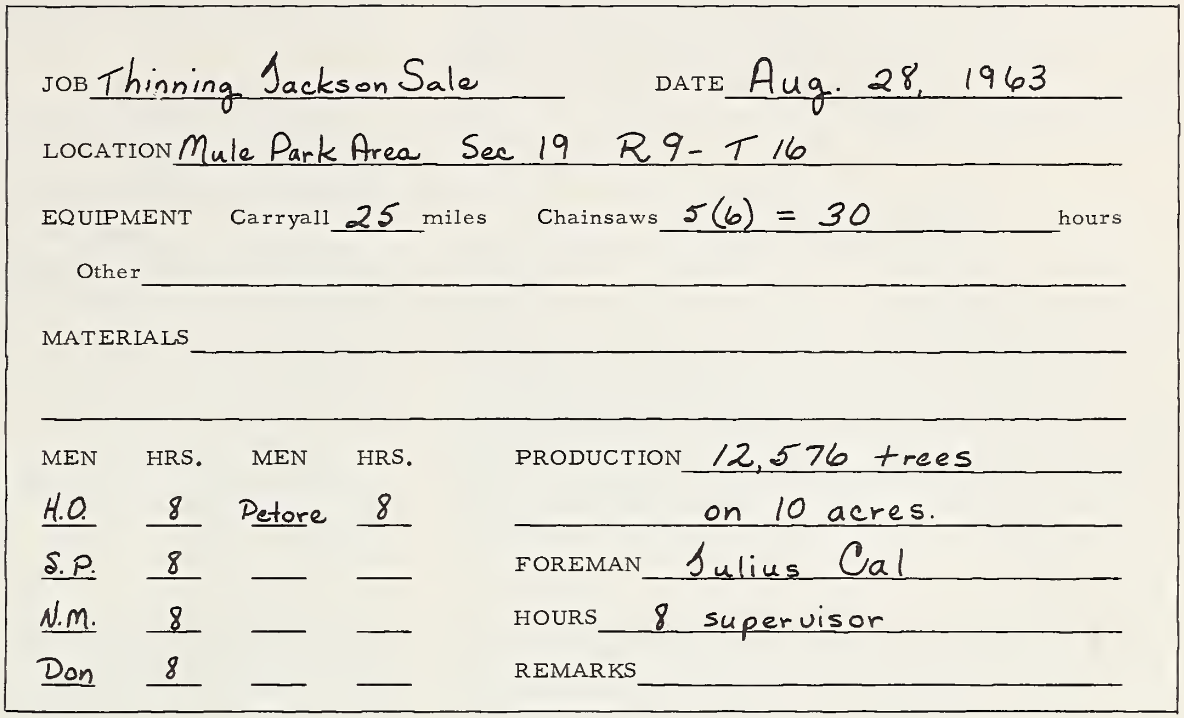
PRODUCTION SUMMARY

Date	Direct operations			Production
	Pushing	Service	Travel	
	- - - Hours - - -			Acres
May 8	4	3	3/4	4
9	6		3/4	5
10	2		3/4	2
20	6	1/2	3/4	9
21	6	1/2	3/4	8
22	6	1/2	3/4	8
23	6	1/2	3/4	10
24	6	1/2	3/4	7
28	6	1/2	3/4	8
29	6	1/2	3/4	6
June 1	6	1/2	3/4	6
Total	60	7	8-/14	73
	75.25			

COST SUMMARY

Average machine hours per acre	60/73	0.822
Average service hours per acre	7/73	.096
Average travel hours per acre	8.25/73	.113
Average total hours per acre	75.25/73	1.03
Average machine cost per acre	60 × $12 = $7.20/73	$ 9.86
Average total labor cost per acre	75.25 × $3 = 225.75/73	3.10
Average total cost per acre		$12.96

Figure 3.--Production summary for juniper pushing, with computations for physical inputs and costs per unit production.


JOB Thinning Jackson Sale DATE Aug. 28, 1963
LOCATION Mule Park Area Sec 19 R 9 - T 16
EQUIPMENT Carryall 25 miles Chainsaws 5(6) = 30 hours
Other
MATERIALS

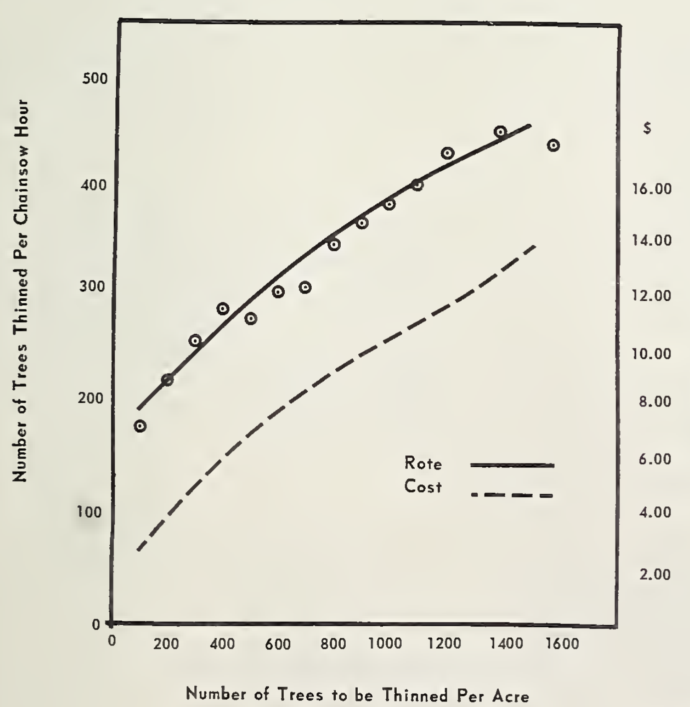
MEN	HRS.	MEN	HRS.
H.O.	8	Petore	8
S.P.	8		
N.M.	8		
Don	8		

PRODUCTION 12,576 trees on 10 acres.
FOREMAN Julius Cal
HOURS 8 supervisor
REMARKS

Figure 4.--Sample of job card with information tallied for 148 daily crew observations on a thinning operation in precommercial ponderosa pine on the Beaver Creek Project.

labor and supervisor inputs shown on the job cards, total field cost was determined to be 1.5 times the direct chainsaw hour cost (fig. 5). The graph of production was developed by grouping the data according to 100-tree classes and drawing a freehand curve through the points. The table of production data was developed from the curve. Costs were then tabled and later graphed to show the cost curve. In this way a useful cost-prediction mechanism was produced for costing future thinning jobs.

Figure 5.--Production and cost curves and table computed from 148 job cards for a thinning operation in precommercial ponderosa pine on the Beaver Creek pilot watersheds.



Number of trees-- To be thinned	Number of trees-- Thinned per hour	Cost per acre
100	195	$ 2.15
200	220	3.80
300	245	5.05
400	270	6.10
500	295	7.15
600	315	7.90
700	340	8.60
800	355	9.30
900	370	10.00
1,000	390	10.60
1,100	410	10.90
1,200	425	11.75
1,300	435	12.40
1,400	445	13.00
1,500	455	13.65

This particular production-rate relation can be followed up in future jobs to determine its broad applicability as illustrated for the juniper pushing case.

Analyzing the costs

Operational Analysis

The whole operation is costed by adding up the costs for the different jobs. Of course, any of the inputs can be added to determine the machine and labor time required to complete an operation. A dollar-cost summation for the juniper-conversion operation on a 400-acre watershed on the Beaver Creek Project (fig. 6) was prepared so cost for each phase could be easily evaluated. It if were decided that $19.41 per acre was too high an investment for converting juniper to grass, the job breakdown and job descriptions could be examined to determine which jobs might be conducted differently to reduce total cost.

It is important to note that some jobs were not applied to all acres. This suggests that, in other cases, some jobs could be eliminated with a per-acre savings approximating the cost in the last column. In other situations, more area might need to be subjected to a particular job and that cost would rise. Each individual conversion, then, will be a unique operation, and the proportional acreage where each job is required should be determined. Thus, we cannot generalize from the total costs on this test area, but must restrict our attention to the unit costs and their expected variation to be applied to another operation.

Such generalization would be considerably easier if we could restrict our attention to specific jobs and/or job elements to which total costs are sensitive. By sensitive, we mean that the expected cost variation in individual jobs would make a big difference in total cost. A sensitivity analysis can be made from one, or at most half a dozen, properly documented case histories to indicate jobs needing improved methods or additional evaluation for prediction purposes.

Sensitivity Analysis

A sensitivity analysis is made to show which jobs in an operation or which elements

COST SUMMARY

Job	Number of acres covered	Cost per acre	
		Each job	Average on watershed
Cabling	304	$ 5.60	$ 4.25
Pushing	73	12.96	2.35
Hand clearing	16	49.00	1.96
Hand seeding	400	5.64	5.64
Burning	400	.61	.61
Hand chopping	300	2.94	2.22
Reseeding	100	4.72	1.18
Direct supervision	400	.55	.55
Travel (mileage)	400	.65	.65
Total cost per acre			$19.41

Figure 6.--Dollar-cost summary to illustrate the operational cost analysis method. Data shown are for a juniper-conversion operation on a 400-acre watershed within the Beaver Creek Project.

of a job can make the biggest difference in total cost. These are:

1. Job areas where greatest managerial care must be exercised to keep costs low, or
2. Job areas where more precise estimating is needed, or
3. Work areas where the manager should look for a new way to perform the element or job.

How much variation to expect in costs is a matter of judgment. If several case histories are available, or if the variation within a case history is available, we have a basis to help sharpen judgment. For example, 10 to 15 percent and no more than 20 percent variation in pushing costs would be expected from the internal analysis of the juniper-clearing case history presented earlier.

When the data were tabulated to make a sensitivity analysis for the 400-acre juniper conversion operation (fig. 7), results showed that the total cost could be expected to vary as much as 21 percent. Because one-third of the total variation can be expected from the conduct of the cabling job alone, it is the job where greatest cost savings are possible. Careful management will pay off here more

Figure 7.--Example of a sensitivity analysis compiled from data collected for a juniper-conversion operation on a 400-acre watershed within the Beaver Creek Project (see fig. 6).

SENSITIVITY ANALYSIS
FOR JUNIPER-CONVERSION OPERATION
ON A 400-ACRE WATERSHED

Job	Average cost per acre (1)	Likely deviation (2)	Acres to be applied (3)	Proportional average (4)	Effect of deviation on average per-acre cost on the watershed (5)	(6)
		Percent	Number	Percent		
Cabling	$ 5.60	30	304	76	$\frac{0.30\ (0.76)\ (5.60)}{\$19.41}$ (100) =	7%
Pushing	12.96	20	73	18	$\frac{0.20\ (0.18)\ (12.96)}{\$19.41}$ (100) =	2%
Hand clearing	49.00	30	16	4	etc.	3%
Hand seeding	5.64	10	400	100		3%
Burning	.61	30	400	100		1%
Hand chopping	2.94	30	300	75		3%
Burn seeding	4.72	30	100	25		2%
Direct supervision	.55		Indeterminate			
Travel mileage	.65		Indeterminate			
Watershed	$19.41					21%

Columns derived--

(1) From operations cost summary.

(2) Determined by judgment.

(3) From operations cost summary.

(4) Job acreage divided by total acreage.

(5) $\frac{\text{(Col. 2) (Col. 4) (Col. 1)}}{\text{Total cost per acre}}$ (100) equals Col. 6.

(6) Percentage of expected variation.

than elsewhere, and careful costing of this job may be warranted.

Within the cabling job, two independent variables exist--characteristics of the juniper stand and ground conditions. Estimates of cabling cost can be improved by conducting time-and-motion studies or a series of gross time studies on these two variables, which can then be subjected to a regression analysis like the juniper-pushing or thinning analysis discussed earlier. The results will feed back into total cost estimates to help define areas too expensive to convert, or conditions where a new approach should be tried.

Potential Applications

The data-collection and analysis system described in this paper is suitable for developing background cost data for a wide variety of forestry jobs and operations. By setting up field tests as described here on scheduled operations of various kinds, a background of costs will be developed to strengthen the forest manager's hand in planning future management. Rangers will be able to use these data as background locally for estimating similar operations, provided proportional acreage and unit costs are varied according to prospective operational conditions. Access to case-history cost data will sharpen the rangers' insight into ground and cover conditions that might affect costs, thus enabling them to design specific cost studies to help them account for these conditions.

By aggregating those data by Forests and Regions, superior cost data will be available for deciding program priorities, and for budgeting programs once the priority is established.

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